New dynamical gauges of the SM of EW interactions

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A new Lagrangian of EW interactions without spontaneous symmetry breaking, Higgs, and Fadeev-Popov procedure has been constructed. It consists of three parts: $SU(2)_L \times U(1)$ gauge fields, massive fermion fields, and their interactions. In this theory the gauge coupling constants g, g', and fermion masses are the inputs. A new mechanism of $SU(2)_L \times U(1)$ symmetry breaking caused by fermion masses has been found. In the EW theory top quark mass plays a dominant role. This mechanism leads to nonperturbative generation of the gauge fixings and masses of Z and W fields. $m_W^2 = \frac{1}{2}g^2 m_t^2$, $m_Z^2 = \frac{1}{2}\bar{g}^2 m_t^2$, $G_F = \frac{1}{2\sqrt{2}m_t^2}$ are revealed from this theory. The propagators of Z- and W-fields without quadratic divergent terms are derived. Very heavy neutral and charged scalars are dynamically generated from this theory too.

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1. New Lagrangian of EW interactions

In the SM of electroweak interactions(EW) there are spontaneous symmetry breaking, Higgs, and Faddeev-Popov procedure. The theory is successful in many aspects. However, there is no experimental indication for existence of Higgs. Other theoretical approaches: Supersymmetry models, Technichcolor, little Higgs, top quark condensate etc. have been proposed to modify the SM. In this talk a new possible EW theory without introducing any unknown factors is discussed. In both QED or QCD there are three parts: gauge fields, massive fermion fields, and interactions between them. They are two very successful quantum field theories. So far, three parts of the theory of EW interactions $SU(2)_L \times U(1)$ gauge fields, massive fermion fields, and the interactions between $SU(2)_L \times U(1)$ gauge fields and fermions are indeed confirmed experimentally. Therefore, it is worth to study the Lagrangian of EW interactions without spontaneous symmetry breaking and Higgs [1]

$$\mathcal{L} = -\frac{1}{4}A^i_{\mu\nu}A^{i\mu\nu} - \frac{1}{4}B_{\mu\nu}B^{\mu\nu} + \bar{q}\{i\gamma \cdot \partial - m_q\}q$$

$$+ \bar{q}_L\{\frac{g}{2}\tau_i\gamma \cdot A^i + g'\frac{Y}{2}\gamma \cdot B\}q_L + \bar{q}_R g'\frac{Y}{2}\gamma \cdot Bq_R$$

$$+ \bar{l}\{i\gamma \cdot \partial - m_l\}l + \bar{l}_L\{\frac{g}{2}\tau_i\gamma \cdot A^i + g'\frac{Y}{2}\gamma \cdot B\}l_L$$

$$+ \bar{l}_R g'\frac{Y}{2}\gamma \cdot Bl_R. \qquad (1)$$

The structure of this L is the same as QED and QCD. The difference is that the $SU(2)_L \times U(1)$ gauge symmetry is broken by fermion masses. The masses of W and Z bosons cannot be added by hand. The term

$$\frac{1}{q^2 - m^2}\frac{q_\mu q_\nu}{m^2} \qquad (2)$$

of the propagator of massive gauge boson causes problems for renormalization and unitarity. The challenge

for this theory is: generating the masses of gauge bosons while the terms(2) which causes quadratic divergence must be canceled.

2. New mechanism of symmetry breaking

The masses of gauge bosons violate the gauge symmetry. In a gauge field theory they should be the effects of $SU(2)_L \times U(1)$ gauge symmetry breaking. In Eq.(1) $SU(2)_L \times U(1)$ gauge symmetry is broken by the fermion masses. We need to study the relationship between the masses of gauge bosons and fermions. It is found that the fermion masses lead to a new mechanism of chiral symmetry breaking. This mechanism is inspired by Weinberg's second sum rule obtained by current algebra [2]

$$m_a^2 = 2m_\rho^2. \qquad (3)$$

a_1 and ρ mesons are chiral partners and they are degenerate under chiral symmetry. Obviously, Weinberg's second sum rule implicates a new mechanism of chiral symmetry breaking. Current algebra is not a field theory. Based on current algebra and QCD the Lagrangian of a chiral field theory of pseudoscalar, vector, and axial-vector mesons has been constructed as(in the case of two flavor) [3]

$$\mathcal{L} = \bar{\psi}(x)(i\gamma \cdot \partial + \gamma \cdot v + \gamma \cdot a\gamma_5 - mu(x))\psi(x)$$

$$+ \frac{1}{2}m_0^2(\rho_i^\mu \rho_{\mu i} + \omega^\mu \omega_\mu + a_i^\mu a_{\mu i} + f^\mu f_\mu), \qquad (4)$$

where $u = e^{(i\pi+i\eta_0)\gamma_5}$, m is the constituent quark mass which originates in quark condensate. In the limit, $m_q \to 0$, the Lagrangian(4) has global $U(2)_L \times U(2)_R$ symmetry and the a_1 and the ρ fields have the same mass. Integrating out the quark fields, the Lagrangian of the mesons is derived, in which a_1 and ρ are non-abelian gauge fields. This theory is phenomenologically successful. The mass relation between the a_1

and the ρ mesons is derived

$$(1 - \frac{1}{2\pi^2 g^2})m_a^2 = 2m_\rho^2, \qquad (5)$$

where g is the universal coupling constant of this theory[3], which is determined by the decay rate of $\rho \to ee^+$. Eq.(5) modifies Weinberg's second sum rule. In Ref.[2] Weinberg made an assumption which is no longer required in this new theory[3]. This new formula fits the data better than Eq.(3). Obviously, Eq.(5) means a $U(2)_L \times U(2)_R$ chiral symmetry breaking revealed from this theory(4) which is $U(2)_L \times U(2)_R$ symmetric at tree level. How the a_1 meson gains additional mass and where the additional factor $(1 - \frac{1}{2\pi^2 g^2})$ comes from? The a_1 field is coupled to the axial-vector current of the massive fermion. Because this current is not conserved the vacuum polarization of the a_1 field is expressed as

$$\Pi_{\mu\nu}^{ij}(q^2) = \int d^4x e^{iqx}$$

$$< 0|T\{\bar{\psi}(x)\gamma_\mu\gamma_5\tau_i\psi(x)\bar{\psi}(0)\gamma_\mu\gamma_5\tau_j\psi(0)\}|0 >$$

$$= \delta_{ij}\{F_1(q^2)(q_\mu q_\nu - q^2 g_{\mu\nu}) + F_2(q^2)q_\mu q_\nu + \frac{1}{2}\Delta m^2 g_{\mu\nu}\}.(6)$$

F_2 and Δm^2 are the results of the nonconserved axial-vector current of the massive quark. They vanish when $m \to 0$. Because of nonconservation of the axial-vector current $F_1(q^2)$ is different from the one of the ρ field. $F_1(q^2)$ is used to normalize the a_1 field and the additional factor is resulted in $F_1(q^2)$.

$$\Delta m^2 = 6m^2, \quad m_\rho^2 = 6m^2. \qquad (7)$$

Eq.(5) is obtained. F_2 is finite and it is the gauge fixing of the nonabalian a_1 field. Therefore, the gauge fixing and additional mass term of a_1 field are dynamically generated from this theory. In the Lagrangian(4) there are no kinetic terms for the meson fields, which are generated from quark loop diagrams. The quark loop diagrams must be treated nonperturbatively. According to Eq.(4), only one quark-loop diagrams are allowed to be calculated. The gauge fixing and additional mass term of a_1 field are nonperturbative solutions of this theory. This is the **new mechanism of symmetry breaking**: nonconserved axial-vector current of massive quark leads to nonperturbative generation of both new mass term and gauge fixing of the a_1 field. In Ref.[3] the the vacuum polarization of the a_1 field has been calculated to the 4th in covariant derivatives. Besides the new mass form formula(5) all the three terms of Eq.(6) have been tested in studying a_1-related meson physics. Without them PCAC cannot be satisfied in this theory. Therefore, the mechanism is supported by a_1-related meson physics. On the

other hand, if ignoring the term $\frac{1}{2}m_0^2 a_i^\mu a_{\mu i}$ of Eq.(3), the mass of the gauge boson is via this mechanism dynamically generated by fermion mass, while the gauge fixing is simultaneously generated by this new mechanism to cancel the term which causes quadratic divergence. Therefore, this mechanism does solve the problem mentioned above. In this mechanism fermion mass is the origin of the mass of gauge boson and gauge fixing. It has been studied in Ref.[1] that the finite F_2 leads to a scalar field.

A charged vector current of massive fermions is not conserved too. The vacuum polarization of a charged vector current of massive fermions takes the same expression as Eq.(6). Besides F_1 there are F_2 and Δm^2 too and they vanish when the masses of fermions go to zero[1]. Therefore, nonconserved charged vector current of massive fermions leads to nonperturbative generation of both new mass term and gauge fixing of the charged vector fields. In Ref.[1] a model has been constructed to show this mechanism

$$\mathcal{L} = i\bar{u}\gamma \cdot \partial u + i\bar{d}\gamma \cdot \partial d + \bar{u}\gamma_\mu dv_\mu^- + \bar{d}\gamma_\mu uv_\mu^+$$

$$- m_u \bar{u}u - m_d \bar{d}d. \qquad (8)$$

The amplitude of the vacuum polarization is derived

$$\Pi_{\mu\nu}^v = \frac{1}{2}(q_\mu q_\nu - p^2 g_{\mu\nu})F_{v1}(q^2) + F_{v2}(q^2)q_\mu q_\nu$$

$$+ \frac{1}{2}m_v^2 g_{\mu\nu}. \qquad (9)$$

$m_u \neq m_d$ leads to $F_{v2}(q^2)$ and m_v^2. The expressions of $F_{v1}(q^2)$, $F_{v2}(q^2)$, and m_v^2 can be found in Ref.[1].

In The Lagrangian(1) the Z-field is coupled to axial-vector currents of massive fermions and W-fields are coupled to charged vector currents of massive fermions. The new mechanism of symmetry breaking can be applied to this EW theory. In Eq.(1) there are no mass terms for the gauge fields and the gague symmetries are broken by the fermion masses, the propagators of gauge bosons cannot be defined and perturbation theory related to gauge fields cannot be defined at the tree level. In order to construct the perturbation theory the vacuum polarizations of Z- and W-fields must be treated nonperturbatively. The masses and gauge fixings of Z and W fields are via this new mechanism dynamically generated from this theory. They are nonperturbative solutions of Eq.(1). As shown above, fermion mass plays essential role in this new mechanism. There is very special effect in the EW theory: the heavy top quark of the EW theory(1) provides strong strength for the symmetry breaking.

3. m_Z, propagator of Z-field, neutral scalar

The couplings between Z-field and fermions are found from Eq.(1). We start from the t- and b-quark generation. The coupling between Z-boson and t and b quarks is found

$$\mathcal{L} = \frac{\bar{g}}{4}\{(1-\frac{8}{3}\alpha)\bar{t}\gamma_\mu t + \bar{t}\gamma_\mu\gamma_5 t\}Z^\mu$$

$$-\frac{\bar{g}}{4}\{(1-\frac{4}{3}\alpha)\bar{b}\gamma_\mu b + \bar{b}\gamma_\mu\gamma_5 b\}Z^\mu, \quad (10)$$

where $\alpha = sin^2\theta_W$. In Eq.(10) there are axial-vector currents of massive t- and b- quarks. Other generations of quarks and leptons can be added. The vacuum polarization of Z-field is expressed as

$$\Pi^Z_{\mu\nu} = \frac{1}{2}F_{Z1}(z)(p_\mu p_\nu - p^2 g_{\mu\nu}) + F_{Z2}(z)p_\mu p_\nu + \frac{1}{2}m_Z^2 g_{\mu\nu}, \quad (11)$$

$$F_{Z1} = 1 + \frac{\bar{g}^2}{64\pi^2}\{\frac{D}{12}\Gamma(2-\frac{D}{2})[N_C y_q \sum_q (\frac{\mu^2}{m_q^2})^{\frac{\epsilon}{2}}$$

$$+ y_l \sum_l (\frac{\mu^2}{m_l^2})^{\frac{\epsilon}{2}}]$$

$$- 2[N_C y_q \sum_q f_1(z_q) + y_l \sum_l f_1(z_l)]$$

$$+ 2[\sum_q f_2(z_q) + \sum_{l=e,\mu,\tau} f_2(z_l)]\},$$

$$F_{Z2} = -\frac{\bar{g}^2}{64\pi^2}\{N_C \sum_q f_2(z_q) + \sum_{l=e,\mu,\tau} f_2(z_l)\},$$

$$m_Z^2 = \frac{1}{8}\frac{\bar{g}^2}{(4\pi)^2}D\Gamma(2-\frac{D}{2})\{N_c \sum_q m_q^2(\frac{\mu^2}{m_q^2})^{\frac{\epsilon}{2}}$$

$$+ \sum_l m_l^2(\frac{\mu^2}{m_l^2})^{\frac{\epsilon}{2}}\}. \quad (12)$$

where $y_q = 1 + (1-\frac{8}{3}\alpha)^2$ for $q = t,c,u$, $y_q = 1 + (1-\frac{4}{3}\alpha)^2$ for $q = b,s,d$, $y_l = 1 + (1-4\alpha)^2$, for $l = \tau,\mu,e$, $y_l = 2$ for $l = \nu_e,\nu_\mu,\tau_\mu$, $z_i = \frac{p^2}{m_i^2}$ and the functions $f_{1,2}$ are defined

$$f_1(z) = \int_0^1 dx x(1-x)log\{1-x(1-x)z\},$$

$$f_2(z) = \frac{1}{z}\int_0^1 dx log\{1-x(1-x)z\}. \quad (13)$$

Both the vector and axial-vector couplings contribute to F_{Z1}, which is used to renormalize the Z-field.

m_Z^2 is resulted in the axial-vector current of massive fermions. If $m_f \to 0$, m_Z^2 goes to zero too. The fermion masses are the origin of the mass of Z-boson. In Eq.(11) there are divergences and renormalization are required. In the Lagrangian(1) there is no mass term of Z-field which, $\frac{1}{2}m_Z^2 Z_\mu Z_\mu$, is dynamically generated. It is better to do the renormalization of m_Z^2. Eq.(12) shows $m_Z^2 \propto m_f^2$ and top quark mass is dominant. Ignoring all other fermion masses, it is obtained

$$m_Z^2(physical) = \frac{N_C}{(4\pi)^2}\frac{D}{4}\Gamma(2-\frac{D}{2})(\frac{\mu^2}{m_t^2})^{\frac{\epsilon}{2}}m_Z^2, \quad (14)$$

$$m_Z^2(physical) = \frac{1}{2}\bar{g}^2 m_t^2. \quad (15)$$

This formula agrees with data very well.

Only the axial-vector coupling contributes to F_{Z2}. F_{Z2} is finite and negative. F_{Z2} vanishes when the fermion masses are taken to be zero. F_{Z2} means a new scalar field ϕ^0[1].

$$F_{Z2}(z) = \xi_Z + (p^2 - m_{\phi^0}^2)G_{Z2}(p^2), \quad (16)$$

where $m_{\phi^0}^2$ is the mass of the new neutral spin-0 field, G_{Z2} is the radiative correction of this term, and ξ_Z is the gauge fixing parameter

$$\xi_Z = F_{Z2}|_{p^2=m_{\phi^0}^2}. \quad (17)$$

The new free Lagrangian of the Z-field is constructed as

$$\mathcal{L}_{Z0} = -\frac{1}{4}(\partial_\mu Z_\nu - \partial_\nu Z_\mu)^2 + \xi_Z(\partial_\mu Z^\mu)^2 + \frac{1}{2}m_Z^2 Z_\mu^2. \quad (18)$$

It is a Stueckelberg's Lagrangian. $\partial_\mu Z^\mu$ is a scalar field

$$\partial^2(\partial_\mu Z^\mu) - \frac{m_Z^2}{2\xi_Z}(\partial_\mu Z^\mu) = 0,$$

$$Z_\mu = Z'_\mu \pm \frac{1}{m_Z}\partial_\mu\phi^0,$$

$$\partial_\mu Z'^\mu = 0,$$

$$\phi^0 = \mp\frac{m_Z}{m_{\phi^0}^2}\partial_\mu Z^\mu,$$

$$\partial^2\phi^0 - \frac{m_Z^2}{2\xi_Z}\phi^0 = 0. \quad (19)$$

The mass of ϕ^0 is the solution of the equation

$$2m_{\phi^0}^2 F_{Z2}|_{p^2=m_{\phi^0}^2} + m_Z^2 = 0,$$

$$m_{\phi^0}^2 = -\frac{m_Z^2}{2\xi_Z}. \tag{20}$$

The equation is expressed as

$$3\sum_q \frac{m_q^2}{m_Z^2} z_q f_2(z_q) + \sum_l \frac{m_l^2}{m_Z^2} z_l f_2(z_l) = \frac{32\pi^2}{\bar{g}^2}. \tag{21}$$

For $z > 4$ it is found

$$f_2(z) = -\frac{2}{z} - \frac{1}{z}(1-\frac{4}{z})^{\frac{1}{2}} log\frac{1-(1-\frac{4}{z})^{\frac{1}{2}}}{1+(1-\frac{4}{z})^{\frac{1}{2}}}. \tag{22}$$

Top quark dominates this equation and it has a solution at very large value of z

$$\frac{2(4\pi)^2}{\bar{g}^2} + \frac{6m_t^2}{m_Z^2} = 3\frac{m_t^2}{m_Z^2} log\frac{m_{\phi^0}^2}{m_t^2},$$

$$m_{\phi^0} = m_t e^{\frac{m_Z^2}{m_t^2}\frac{16\pi^2}{3\bar{g}^2}+1} = m_t e^{28.4} = 3.78 \times 10^{14} GeV. \tag{23}$$

The dynamically generated scalar is very heavy.

$$\xi_Z = -1.18 \times 10^{-25}. \tag{24}$$

The propagator of Z boson is found

$$\Delta_{\mu\nu} = \frac{1}{q^2 - m_Z^2}\{-g_{\mu\nu} + (1+\frac{1}{2\xi_Z})\frac{q_\mu q_\nu}{q^2 - m_{\phi^0}^2}\}, \tag{25}$$

It can be separated into two parts

$$\Delta_{\mu\nu} = \frac{1}{p^2 - m_Z^2}\{-g_{\mu\nu} + \frac{p_\mu p_\nu}{m_Z^2}\}$$

$$-\frac{1}{m_Z^2}\frac{q_\mu p_\nu}{q^2 - m_{\phi^0}^2}. \tag{26}$$

The first part is the propagator of the physical spin-1 Z boson and the second part is the propagator of a new neutral spin-0 meson, ϕ^0. The minus sign of the scalar part indicates that the scalar has negative metric.

The couplings between $\partial_\mu\phi^0$ and fermions are found

$$\mathcal{L} = \pm\frac{1}{m_Z}\frac{\bar{g}}{4}\{(1-\frac{8}{3}\alpha)\bar{t}\gamma_\mu t + \bar{t}\gamma_\mu\gamma_5 t\}\partial_\mu\phi^0$$

$$\pm\frac{1}{m_Z}\frac{\bar{g}}{4}\{-(1-\frac{4}{3}\alpha)\bar{b}\gamma_\mu b - \bar{b}\gamma_\mu\gamma_5 b\}\partial_\mu\phi^0$$

$$\pm\frac{1}{m_Z}\frac{\bar{g}}{4}\{\bar{\nu}_e\gamma_\mu(1+\gamma_5)\nu_e - (1-4\alpha)\bar{e}\gamma_\mu e$$

$$-\bar{e}\gamma_\mu\gamma_5 e\}\partial_\mu\phi^0. \tag{27}$$

The couplings with other generations of fermions take the same form. Using the equations of fermions, it can be found that the couplings between ϕ^0 and fermions are

$$\pm\frac{1}{m_Z}\frac{\bar{g}}{4}2i\sum_i m_i\bar{\psi}_i\gamma_5\psi_i\phi^0, \tag{28}$$

where i stands for the type of fermion. Eq.(28) shows that the coupling between ϕ^0 and fermion is proportional to the mass of the fermion. The couplings between ϕ^0 and intermediate bosons can be obtained too. It is necessary to point out that because ther propagators of the gauge fields cannot be defined from Eq.(1), only single fermion-loops are allowed to be calculated.

4. m_W, propagator of W-field, charged scalars

The couplings between W-fields and fermions are found from Eq.(1)

$$\mathcal{L} = \frac{g}{4}\bar{\psi}\gamma_\mu(1+\gamma_5)\tau^i\psi W^{i\mu}, \tag{29}$$

Charged axial-vector and vector currents of massive fermions are shown in eq.(29). Therefore, the new mechanism of symmetry breaking can be applied. The expression of the vacuum polarization of fermions is obtained

$$\Pi_{\mu\nu}^W = F_{W1}(p^2)(p_\mu p_\nu - p^2 g_{\mu\nu}) + 2F_{W2}(p^2)p_\mu p_\nu + m_W^2 g_{\mu\nu}, \tag{30}$$

where

$$F_{W1}(p^2) = 1 + \frac{g^2}{32\pi^2}D\Gamma(2-\frac{D}{2})\int_0^1 dxx(1-x)$$

$$\{N_C\sum_{iq}(\frac{\mu^2}{L_q^i})^{\frac{\epsilon}{2}} + \sum_{il}(\frac{\mu^2}{L_l^i})^{\frac{\epsilon}{2}}\}$$

$$-\frac{g^2}{16\pi^2}\{N_C\sum_{iq}f_{1q}^i + \sum_{il}f_{1l}^i\}$$

$$+\frac{g^2}{16\pi^2}\{N_C\sum_{iq}f_{2q}^i + \sum_{il}f_{2l}^i\}, \tag{31}$$

$$F_{W2}(p^2) = -\frac{g^2}{32\pi^2}\{N_C\sum_{iq}f_{2q}^i + \sum_{il}f_{2l}^i\}, \tag{32}$$

$$m_W^2 = \frac{g^2}{4}\frac{1}{(4\pi)^2}D\Gamma(2-\frac{D}{2})\int_0^1 dx\{N_c\sum_{iq}L_q^i(\frac{\mu^2}{L_q^i})^{\frac{\epsilon}{2}}$$

$$+\sum_{il}L_l^i(\frac{\mu^2}{L_l^i})^{\frac{\epsilon}{2}}\}. \tag{33}$$

where

$$L_q^1 = m_b^2 x + m_t^2(1-x),$$

$$L_q^2 = m_s^2 x + m_c^2(1-x),$$

$$L_q^3 = m_d^2 x + m_u^2(1-x), \qquad (34)$$

$$L_l^1 = m_e^2 x,$$

$$L_l^2 = m_\mu^2 x,$$

$$L_l^3 = m_\tau^2 x,$$

$$f_{1q}^i = \int_0^1 dx x(1-x)log[1 - x(1-x)\frac{p^2}{L_q^i}] \qquad (35)$$

$$f_{1l}^i = \int_0^1 dx x(1-x)log[1 - x(1-x)\frac{p^2}{L_l^i}], \qquad (36)$$

$$f_{2q}^i = \frac{1}{p^2}\int_0^1 dx L_q^i log[1 - x(1-x)\frac{p^2}{L_q^i}], \qquad (37)$$

$$f_{2l}^i = \frac{1}{p^2}\int_0^1 dx L_l^i log[1 - x(1-x)\frac{p^2}{L_l^i}]. \qquad (38)$$

The function $F_{W1}(p^2)$ is used to renormalize the W-fields.

m_W^2 is via the new mechanism originated in fermion masses. The mass term, $m_W^2 W_\mu^+ W^{-\mu}$, is dynamically generated. It is required to do mass renormalization of W-fields. Once again, top quark mass is dominant in m_W^2. Ignoring all other fermion masses, it is obtained

$$m_W^2(physical) = \frac{N_C}{(4\pi)^2}\frac{D}{4}\Gamma(2 - \frac{D}{2})(\frac{\mu^2}{m_t^2})^{\frac{\epsilon}{2}}m_W^2, \quad (39)$$

$$m_W^2(physical) = \frac{1}{2}g^2 m_t^2. \qquad (40)$$

This formula agrees with data very well.

Using Eqs.(15,40), it is obtained

$$\frac{m_W^2}{m_Z^2} = \frac{g^2}{\bar{g}^2} = cos^2\theta_W. \qquad (41)$$

$$G_F = \frac{1}{2\sqrt{2}m_t^2}. \qquad (42)$$

The study of the correction of Eqs.(15,40,41,42) can be done.

The F_{W2} is finite. It is via the new mechanism obtained. When $m_f \rightarrow 0$, it goes to zero. F_{W2} is negative and leads to the existence of two charged spin-0 states, $\phi^\pm$. F_{W2} is rewritten as

$$F_{W2} = \xi_W + (p^2 - m_{\phi_W}^2)G_{W2}(p^2), \quad (43)$$

$$\xi_W = F_{W2}(p^2)|_{p^2=m_{\phi_W}^2}, \qquad (44)$$

where G_{W2} is the radiative correction of the term $(\partial_\mu W^\mu)^2$ and $m_{\phi_W}^2$ is the mass of the charged spin-0 states, $\phi^\pm$. The free part of the Lagrangian of W-field is redefined as

$$\mathcal{L}_{W0} = -\frac{1}{2}(\partial_\mu W^{+\nu} - \partial_\nu W_\mu^+)(\partial_\mu W_\nu^- - \partial_\nu W_\mu^-)$$

$$+ 2\xi_W\partial_\mu W^{+\mu}\partial_\nu W^{-\nu} + m_W^2 W_\mu^+ W^{-\mu}. \qquad (45)$$

It is a Stueckelberg's Lagrangian.

The divergences of the W-fields are independent degrees of freedom

$$\partial^2(\partial_\mu W^{\pm\mu}) - \frac{m_W^2}{2\xi_W}(\partial_\mu W^{\pm\mu}) = 0. \qquad (46)$$

$\partial_\mu W^{\pm\mu}$ are spin-0 fields. Therefore, the W field of the SM has four independent components. The W-field is decomposed as

$$W_\mu^\pm = W_\mu'^\pm \pm \frac{1}{m_W}\partial_\mu\phi^\pm, \qquad (47)$$

$$\partial_\mu W'^{\pm\mu} = 0, \qquad (48)$$

$$\phi^\pm = \mp\frac{m_W}{m_{\phi_W}^2}\partial_\mu W^{\pm\mu}, \qquad (49)$$

where W' is a massive spin-1 field and $\phi^\pm$ are spin-0 fields. The equation of $\phi^\pm$ is derived from Eqs.(46)

$$\partial^2\phi^\pm - \frac{m_W^2}{2\xi_W}\phi^\pm = 0. \qquad (50)$$

The mass of $\phi^\pm$ is determined by the equation

$$2m_{\phi_W}^2 F_{W2}(p^2)|_{p^2=m_{\phi_W}^2} + m_W^2 = 0 \qquad (51)$$

and

$$m_{\phi_W}^2 = -\frac{m_W^2}{2\xi_W}. \qquad (52)$$

Numerical calculation shows that top quark is dominant in F_{W2}. Keeping the contribution of top quark only, Eq.(51) becomes

$$\frac{p^2}{m_W^2}F_{W2} = -\frac{3g^2}{32\pi^2}\frac{m_t^2}{m_W^2}\{-\frac{3}{4}+\frac{1}{2z}+[\frac{1}{2}-\frac{1}{z}+\frac{1}{2z^2}]log(z-1)\}, \qquad (53)$$

where $z = \frac{p^2}{m_t^2}$. Eq.(53) has a solution at very large z. At very large z we have

$$\frac{p^2}{m_W^2}F_{W2} = -\frac{3g^2}{64\pi^2}\frac{m_t^2}{m_W^2}log z. \qquad (54)$$

The mass of $\phi^\pm$ is determined to be

$$m_{\phi_W} = m_t e^{\frac{16\pi^2}{3g^2}\frac{m_W^2}{m_t^2}} = m_t e^{27} = 9.31 \times 10^{13} GeV, \qquad (55)$$

and

$$\xi_W = -3.73 \times 10^{-25}.$$

The charged $\phi^{\pm}$ are very heavy too.

The propagator of W-field is derived from Eq.(45)

$$\Delta_{\mu\nu}^{W} = \frac{1}{p^2 - m_W^2}\{-g_{\mu\nu} + (1 + \frac{1}{2\xi_W})\frac{p_\mu p_\nu}{p^2 - m_{\phi_W}^2}\},$$
$$(56)$$

and it can be separated into two parts

$$\Delta_{\mu\nu}^{W} = \frac{1}{p^2 - m_W^2}\{-g_{\mu\nu} + \frac{p_\mu p_\nu}{m_W^2}\} - \frac{1}{m_W^2}\frac{p_\mu p_\nu}{p^2 - m_{\phi_W}^2}.$$
$$(57)$$

The first part of Eq.(57) is the propagator of physical spin-1 W-field and the second part is related to the propagator of the $\phi^{\pm}$ field.

As shown above, the gauge fixings ξ_z and ξ_W are dynamically generated and their values are fixed. There are no other ghosts associated with these gauge fixings. Therefore, this scheme is completely different with Fadeev-Popov procedure of the SM.

The Lagrangian of interactions between fermions and $\partial_\mu \phi^{\pm}$ field is found from Eqs.(29,47)

$$\mathcal{L}_{q\phi} = \pm\frac{1}{m_W}\frac{g}{4}\sum_j \bar{\psi}_j \gamma_\mu (1 + \gamma_5)\tau^i \psi_j \partial^\mu \phi^i, \qquad (58)$$

where j is the type of the fermion and

$$\phi^1 = \frac{1}{\sqrt{2}}(\phi^+ + \phi^-) \quad \phi^2 = \frac{1}{\sqrt{2}i}(\phi^+ - \phi^-). \qquad (59)$$

Using the dynamical equations of fermions of the SM, for t and b quark generation we obtain

$$\mathcal{L}'_{q\phi} = \pm\frac{i}{m_W}\frac{g}{4}(m_t + m_b)\{\bar{\psi}_t \gamma_5 \psi_b \phi^+ + \bar{\psi}_b \gamma_5 \psi_t \phi^-\}.$$
$$(60)$$

The coupling is proportional to the fermion mass. The couplings between other generations of fermion and $\phi^{\pm}$ field are similar to Eq.(60).

It is interesting to notice that coupling between the charged scalars and the photon takes the form

$$\mathcal{L} = \frac{4ie}{m_W^2}F^{\mu\nu}\partial_\mu \phi^+ \partial_\nu \phi^-. \qquad (61)$$

The strength of the electromagnetic interactions is at the order of weak interactions.

5. perturbation theory

Using Eqs.(18,45) and the free Lagrangian of fermions(1), the perturbation theory of this new EW theory can be constructed.

6. Conclusions

In the new theory of EW interactions(1) the gauge couplings g, g', and fermion masses are the parameters of this theory. A new mechanism of symmetry breaking by fermion masses has been found. This new mechanism is supported by meson physics. In EW theory(1) top quark mass plays dominant role in this mechanism. Gauge fixings and masses of Z and W bosons are via this new mechanism dynamically generated. They are nonperturbative solutions of this theory. New propagators of Z- and W-fields are derived, in which there are no quadratic divergent terms. A neutral and charged scalar fields are nonperturbative solutions of this EW theory. These scalar fields have negative metric. Perturbation theory is constructed. It is worth to point out that the gauge fixings and heavy scalar fields are still nonperturbative solutions of the SM of EW interactions with spontaneous symmetry breaking and Higgs. In the new perturbation of theory of the SM Fadeev-Popov procedure is no longer required. The question can be asked is that from the new mechanism the scalar bosons can be dynamically generated why we need to add Higgs to theory by hand.

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